CAB INTERNATIONAL
MYCOLOGICAL INSTITUTE
LIBRARY
18 FEB 1992
GOULDEN, C.H.

1930

# THE RELATION BETWEEN STEM RUST INFECTION AND THE YIELD OF WHEAT *

C. H. GOULDEN and F. J. GREANEY
*Dominion Rust Research Laboratory, Winnipeg, Man.*

*Reprinted from Scientific Agriculture, Vol. X., No. 6, February, 1930.*

# THE RELATION BETWEEN STEM RUST INFECTION AND THE YIELD OF WHEAT *

C. H. GOULDEN and F. J. GREANEY †
*Dominion Rust Research Laboratory, Winnipeg, Man.*

[Received for publication November 25, 1929]

In previous studies on the influence of rust on the yield of cereal crops the method employed has been to correlate rust percentage with yield in a heterogeneous group of varieties and strains. Among such groups there are varying degrees of rust resistance and consequently varying percentages of rust are obtained which can be correlated with yield. These studies have given quite definite results. Goulden and Elders (*4*, 1926), with a group of 146 wheat varieties, studied all possible relations between yield, susceptibility to stem rust, susceptibility to leaf rust, earliness, and strength of straw. They obtained the partial correlation coefficient — .722 ± .027 for the relation between yield and susceptibility to stem rust, and — .456 ± .044 for yield and susceptibility to leaf rust; Hayes, Aamodt, and Stevenson (*6*, 1927), in a similar study, found stem and leaf rust to be quite significantly associated with the yield of spring wheats and that stem rust was significantly associated with the yield of winter wheats. From data on a group of oat varieties and strains, Immer and Stevenson (*7*, 1928), found a significant association between crown rust and yield.

The method of correlating rust percentage with yield in a heterogeneous group of strains has given results demonstrating the extreme importance of rust as a factor in cereal crop production and of the concurrent importance of the use of resistant varieties. However, as pointed out by Goulden and Elders in 1926—"in the interpretation of these results it must be borne in mind that the data were obtained from a group of wheat varieties which one would not be justified in assuming to be a random sample." The results were quite definite for the material studied but with another and entirely distinct group of varieties the value of the correlation obtained might be somewhat different. This point may be more clearly brought out by the consideration of a theoretical case. Let us assume that the varieties tested may be divided into four categories on the basis of rust resistance, these categories being (1) resistant, (2) moderately resistant, (3) moderately susceptible and (4) susceptible. Obtaining a true correlation value between the amount of rust and yield is then based on the assumption that the intrinsic yielding capabilities of the four groups, i.e. their average yields when rust is not a factor, are approximately the same. If the resistant varieties give lower yields than the susceptible varieties when rust is not a factor, the numerical value of the correlation coefficient will be too low; and conversely, if the resistant varieties are the best yielders under such conditions, the numerical value of the correlation coefficient will be too high.

It was these facts which were generally referred to, in the 1926 publication, in the statement regarding the inadequacy of the heterogeneous

*Joint contribution from the Cereal Division and Botany Division, Dominion Department of Agriculture, Canada.
†Senior Cereal Specialist and Plant Pathologist, respectively.

group of varieties as a purely random sample. They have led furthermore to the planning of an experiment in which the different amounts of rust on a *single standard variety* could be correlated with yield. The information from such an experiment it was thought would be of considerable value in estimating yields for crop reports. There seems to be a tendency in estimating rust losses to neglect entirely the effect of a ten or fifteen per cent infection of rust. Consequently experimental results showing the exact effect of such small infections should materially assist in the process of estimation.

## Experimental Methods

The main part of the experiment was conducted on a block of land sown to Marquis wheat and divided into 196, 1/400th acre plots. These were arranged in the form of a 14 × 14 Latin Square in which the amounts of rust on different replicates were varied by different rates and frequency of application of sulphur dust. Previous experiments, Bailey and Greaney (*1,* 1925, *2,* 1928), and Greaney (*5,* Rept. of Dom. Bot., Can. Dept. Agr. 1928), had indicated that by such treatment all gradations of rust infection could be obtained and it seemed, therefore, to be a very convenient method to apply for the purpose of this study. In the 14 × 14 Latin Square, 13 treatments were worked out, the 14th being the check which was left untreated. The treatments were as given in table 1.

Table 1. *Different methods of treating plots of Marquis wheat with sulphur dust in a 14 × 14 Latin Square in order to give varying percentages of rust.**

| Treatment No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Amount of dust per acre in lbs. | 15 | 15 | 15 | 15 | 15 | 30 | 30 | 30 | 30 | 45 | 45 | 45 | 45 | 0 |
| Interval between applications in days | 21 | 14 | 7 | 4 | 2 | 14 | 7 | 4 | 2 | 14 | 7 | 4 | 2 | |

*the degrees of rust in these plots were read according to the U.S.D.A. standards where 37 per cent of actual surface covered with rust is arbitrarily chosen as 100 per cent.

The results from two other experiments which were conducted by the junior author primarily for the purpose of comparing the efficency of different methods of treatment and of different kinds of sulphur dust for the control of rust, were also incorporated in the present study. These experiments were likewise arranged in the form of Latin Squares, the plots being 1/200 acre in size. The first was an 8 × 8 Latin Square in which four methods of treatment were compared and three kinds of sulphur dust. The second was a 7 × 7 Latin Square in which six kinds of dust were compared directly. The different treatments given in these two squares are listed in table 2. These treatments are given in table 2 merely as a general indication of the treatments the varying effectiveness of which brought about varying amounts of rust in the plots. Complete details of these experiments and the results obtained are given by Greaney in as yet unpublished data.

TABLE 2. *Different sulphur dust treatments given plots of Marquis wheat in two experiments conducted in 8 × 8 and 7 × 7 Latin Squares.*

| Type of Latin Square | TREATMENTS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | No. 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7 × 7 | Kolodust | Koppers dust | Electric dust | Kopper's + lime | Sulfo-dust | Gas dust | None | |
| 8 × 8 | Kolodust before rains | Kolodust after rains | Kolodust direct dusting | Kolodust drifting | Commercial oxidized dust | Kolodust + Oxide 2% | Kolodust + Oxide 5% | None |

## RESULTS AND DISCUSSION

In the analysis of the results from these two experiments rust percentages and yields of individual plots were correlated. In the 14 × 14 experiment the rust percentages varied from zero to 70 per cent although only one plot gave the latter figure and the next highest was 50 per cent. The crop on this block, owing to the drought experienced during the 1929 season, was fairly light. The drought also served to check the development of a heavy rust epidemic. In making a correlation surface for the rust percentages and yields in this block all those plots were discarded which failed to give as high as 5 per cent of rust. There were 85 such plots so that the total number on which data could be obtained was 111.

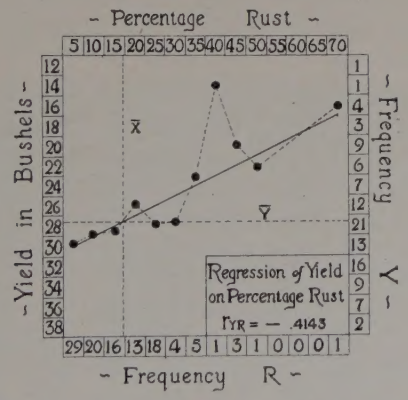


Figure 1. Regression of yield on percentage rust in plots of Marquis wheat in a 14 × 14 Latin Square.

The results from the 14 × 14 Latin Square are given in the form of a regression graph in Figure 1. The correlation coefficient for this group was —.4143. Its significance was tested by the method given by Fisher (*3*). This involves calculating—

$$t = \frac{r}{1 - r^2} \sqrt{n^1 - 1}$$

where $n^1$ is the number of pairs of values entering into the correlation. For our coefficient —.4143 the value of t is 5.24. Using Fisher's tables, it is evident that the odds of significance are considerably greater than 100 : 1 as for these odds a t value of only 2.6 is required. The determination of the regression of yield on percentage rust, while not entirely satisfactory on account of the low frequency of plots with high rust percentages, gives, however, an approximate value for the reduction in yield corresponding to a given increase in the percentage of rust. Here the reduction in yield for each 10 per cent increase of rust is 1.97 bushels. It seems most logical to express this value in per cent of the average yield (28.4 bushels,) of the highest yielding series in the experiment. The highest yielding series was the one given the heaviest sulphur treatment and as nearly as possible represents what the average yield of the entire block would have been if rust had not been present. The reduction of 1.97 bushels represents 6.8 per cent of 28.4 bushels.

In the second experiment the results from the $7 \times 7$ and $8 \times 8$ blocks were combined. These two blocks were very much alike in average yield and average percentage of rust so that combining the results could have only a very slight spurious effect on the value of the correlation coefficient. In fact, in making up the correlation table the blocks were dealt with separately and the swarm of one superimposed on that of the other. The two swarms coincided very closely and easily justified the combination of the two sets of data. The value of the correlation coefficient obtained in this experiment was —.6085 for which the value of t is 10.2. Again this is a very significant value. The regression graph is shown in Figure 2 and we find that for 10 per cent increase of rust the yield is reduced by 3.83 bushels. This is 9.7 per cent of 39.3 the yield in bushels of the series having the most effective treatment for rust control.

The two results considered from the standpoint of the per cent reduction in yield for each 10 per cent of rust are very significant and give us an approximate measure of the reduction in yield to be expected under ordinary conditions. An important point is the uniform reduction in yield as the rust varies from low to high percentages. From the standpoint of the regression graph this is a matter of linearity of regression. To test this the analysis of variance method as developed by Fisher (*3*) was used. In both cases the deviations from the regression straight line are not significant, and this indicates that 10 per cent of rust will reduce the yield to the same extent as an increase in rust from 70 to 80 per cent.

A point of further interest is the difference between the values of the correlation coefficients from the two experiments. On the basis of per cent reduction in yield, the one experiment giving 6.8 per cent and the other 9.7 per cent, the difference does not seem very great but that it is probably significant is evident from a comparison of the correlation coefficients. Applying the z test as developed by Fisher (*3*), we find that z for the difference is .26576 $\pm$ .13546. Thus z is 1.96 times its standard deviation and this is equivalent to odds of 20 : 1. Where the average yield is high the average percentage of rust is high and the reduction in yield per 10 per cent of rust correspondingly greater than where the average yield and rust percentage

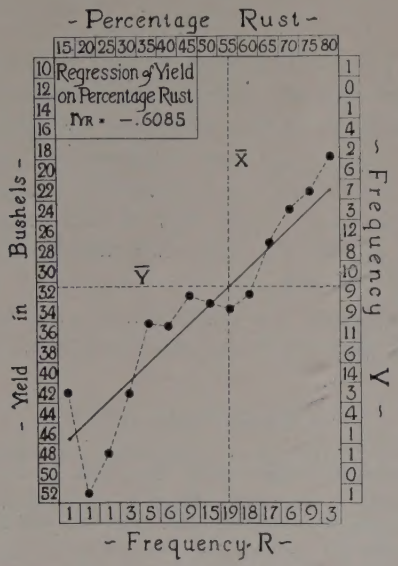


Figure 2. Regression of yield on percentage rust in plots of Marquis wheat from 7 × 7 and 8 × 8 Latin Squares.

is somewhat lower. The straight line regression indicated that for any given set of conditions especially with respect to the heaviness of growth, the relation between amount of rust and reduction in yield is linear but on another field where growth is heavier, while the relation is still linear, the reduction caused by a given amount of rust may be greater than where the growth is light. These points while not definitely proven are certainly indicated by the data from the above experiments.

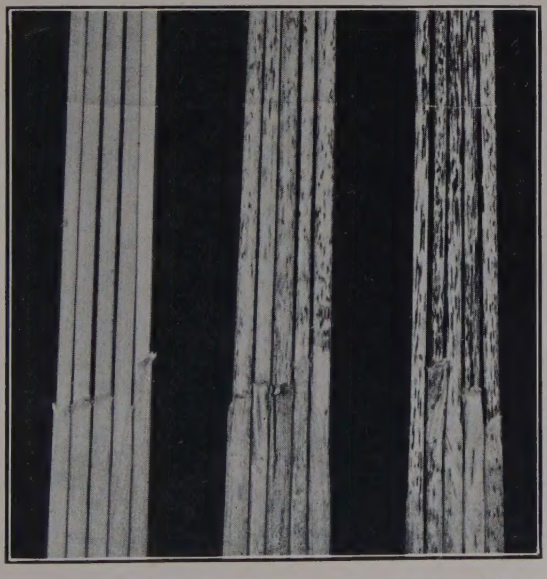

Figure 3. Three samples of Marquis wheat straw from the plots of the 7 × 7 and 8 × 8 experiments showing the range in rust infection. From left to right these infections were read, 0%, 40%, and 80%.

## Summary

1. The amounts of rust in a series of plots of Marquis wheat were varied by different rates and intervals between applications of sulphur dust. The yields of individual plots were then correlated with the rust percentages.

2. The results from two such experiments are summarized in the form of correlation coefficients and regression equations. In one experiment it was found that each 10 per cent of rust reduced the yield approximately 6.8 per cent, and in the other experiment each 10 per cent of rust reduced the yield 9.7 per cent.

3. In both experiments the regression of yield on percentage rust was linear, indicating that uniform increases in rust result in uniform reductions in yield.


## LITERATURE CITED


1. Bailey, D. L., and F. J. Greaney. Preliminary experiments on the control of leaf and stem rust of wheat by sulphur dust. Sci. Agr. *7*: 113-117, 1925.
2. Bailey, D. L., and F. J. Greaney. Dusting with sulphur for the control of leaf and stem rust of wheat in Manitoba. Sci. Agr. *8*: 409-432, 1928.
3. Fisher, R. A. Statistical methods for research workers. Second edition. Oliver and Boyd, Edinburgh, 1928.
4. Goulden, C. H., and A. T. Elders. A statistical study of the characters of wheat varieties influencing yield. Sci. Agr. *6*: 337-345, 1926.
5. Greaney, F. J. Dusting with sulphur for the control of cereal rusts. Rept. Dom. Botanist, Can. Dept. Agr. 1928. (in press).
6. Hayes, H. K., O. S. Aamodt and F. J. Stevenson. Correlation between yielding ability, reaction to certain diseases, and other characters of spring and winter wheat in rod row trials. Jour. Amer. Soc. Agron. *19*: 896-910, 1927.
7. Immer, F. R. and T. J. Stevenson. A biometrical study of factors affecting yield in oats. Jour. Amer. Soc. Agron. *20*: 1107-1119, 1928.